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Research article - Basic and applied anatomy

The patellofemoral joint alignment in patients with symptomatic accessory navicular bone

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Abstract

Quadriceps angle (Q angle) provides useful information about the alignment of the patellofemoral joint. The aim of the present study was to assess a possible link between malalignment of the patellofemoral joint and symptomatic accessory navicular (AN) bone as an underlying cause in early adolescence using Q angle measurements.
This study was performed on patients presenting to the Foot and Ankle Clinic at the Jordanian Royal Medical Services because of pain on the medial side of the foot that worsened with activities or shoe wearing, with no history of knee pain, between September 2013 and April 2015. The Q angle was measured using a goniometer in 27 early adolescents aged 10-18 years diagnosed clinically and radiologically with symptomatic AN bone, only seven patients had associated pes planus deformity; the data were compared with age appropriate normal arched feet without AN. Navicular drop test (NDT) was used to assess the amount of foot pronation.
The mean Q angle value among male and female patients with symptomatic AN with/without pes planus was significantly higher than in controls with normal arched feet without AN ($p<0.05$). Symptomatic AN feet were also associated with higher NDT values ($p<0.001$).
The present findings suggest an early change in patellofemoral joint alignment in patients with symptomatic AN bone with/without arch collapse. Therefore, it is recommended that Q angle assessment should be an essential component of the examination in patients with symptomatic AN bone.

Key words

Q angle, pes planus, patellofemoral joint, accessory navicular, navicular drop test

Introduction

An understanding of the normal anatomical and biomechanical features of the patellofemoral joint is essential to evaluate the patellofemoral joint function and stability. The mechanical analysis of proper alignment and stability of any joint depends mainly on the study of the effect of the structures surrounding that joint (Hehne, 1990). One such method is to study the effect of the muscles working on the joint by applying the principles of vectors on each muscle. The angle that is formed by intersection of the muscles forces vectors gives an insight on the stability of that joint. It is well known that the Quadriceps angle (Q angle) is a meaningful clinical measure to assess the overall lateral line of pull of the quadriceps relative to the patella and pro-

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vides useful information about the alignment of the patellofemoral joint (Biedert and Warnke, 2001; Mizuno et al., 2001; Sanfridsson et al., 2001; Smith et al., 2008).

Q angle was firstly defined as the acute angle formed by the vector for the combined pull of the quadriceps femoris muscle and the patellar tendon (Brattstroem, 1964; Smith et al., 2008). This angle can be measured in supine or standing position with the hip and knee extended and the quadriceps muscle relaxed (Omololu et al., 2009). Many previous investigations have shown people with a larger Q angle (greater than 20 degrees) have a greater likelihood for developing numerous knee complaints (Horton and Hall, 1989).

Accessory navicular (AN) is an accessory ossicle of the foot which is located on the medial side of foot, proximal to the navicular and in continuity with the tibialis posterior tendon. It presents in 4-21% of the population. AN has three types; Type I is a small separated ossicle, sized 2 to 3 mm, located in the distal portion of the tibialis posterior tendon. Type II measures up to 12 mm and is separated from the tuberosity of the navicular bone by less than 2 mm of fibrocartilaginous synchondrosis. Type III is connected to the navicular tuberosity through a bony bridge. Type II and III have been associated with pathologic conditions, often causing an alteration of the line of pull of the tibialis posterior tendon as a result of the AN prominence. This imbalance was thought to weaken the longitudinal arch and produce pronation of the foot (Prichasuk and Sinphurmsukskul, 1995; Ugolini and Raikin, 2004). Pes planus (flatfoot) deformity is characterized by loss of the medial longitudinal arch, forefoot abduction and hindfoot eversion. There are various types and causes of flatfeet. An association has been made between AN and pes planus deformity; nevertheless, the causal relationship is still controversial (Sella et al., 1986; Prichasuk and Sinphurmsukskul, 1995; Leonard and Fortin, 2010; Park et al., 2014).

Based on our clinical experience, middle-aged and elderly patients with long standing painful AN in their feet had frequent anterior knee complaints. For this reason, the aim of the present study was to assess whether symptomatic AN bone could have a possible consequence on malalignment of the patellofemoral joint in early adolescence using the Q angle measurements, in order to improve the diagnosis and early treatment, or prevention of the possible patellofemoral joint problems that might be associated with this type of anatomic variant later in life.

Methods

Measurement of Q angle was recorded from 27 symptomatic patients (9 males, 18 females, age range 10–18 years) presented to our Foot and Ankle Clinic between September 2013 and April 2015 because of pain interfering with walking and sports, or tenderness on the medial side of the foot that worsens with activities or shoe wearing. Written informed consent was taken from each subject's guardian. The research was approved by the Ethics Committee of King Hussein Medical Center according to the ethical principles of Helsinki Declaration. Radiologically, all patients had bilateral AN confirmed by weight-bearing and non weight-bearing anterior-posterior/lateral X rays.

Accessory navicular patients were divided into three groups according to their symptoms. Group 1 was composed of 20 patients with painful AN and normal arch height (14 bilateral and six unilateral painful AN; Fig. 1). Group 2 consisted of seven

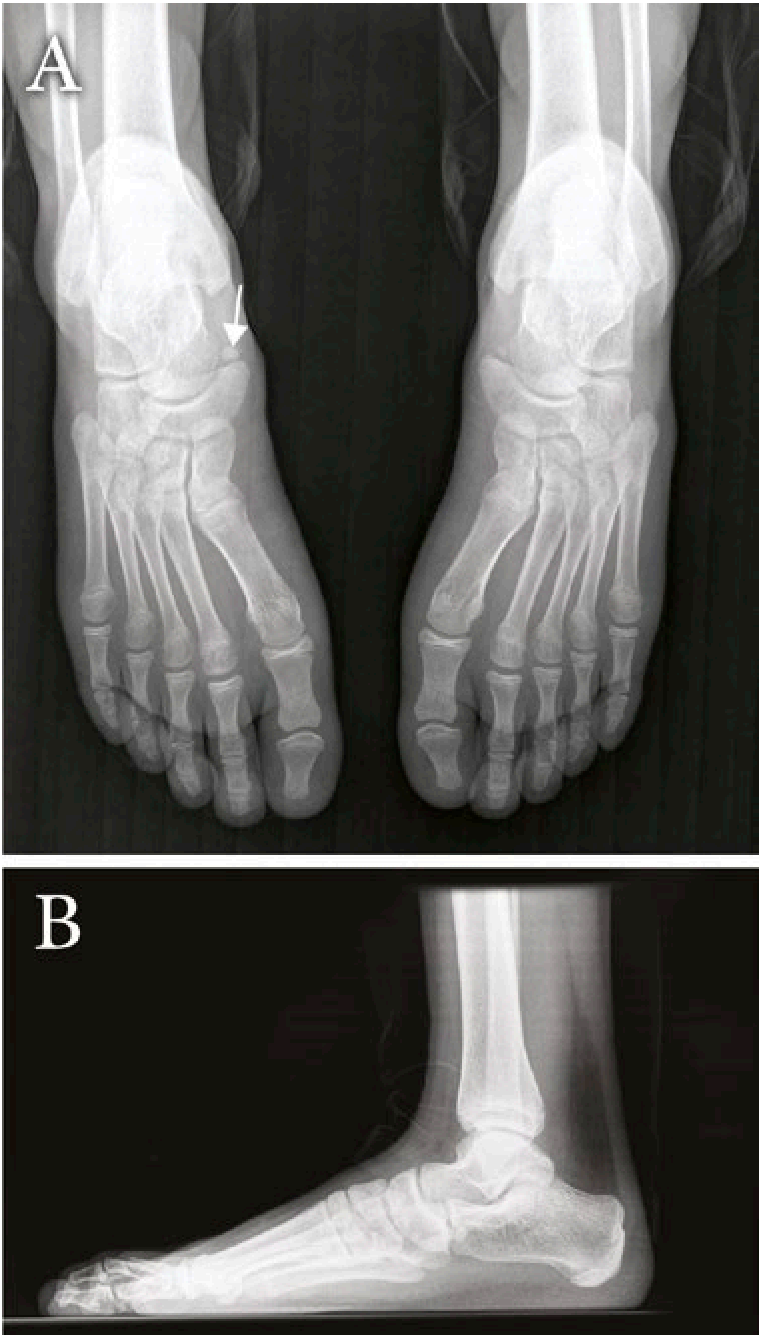

Figure 1 – 14-year old boy with accessory navicular type II (arrow) associated with normal arch. **A**: AP-radiograph shows no midfoot pronation or forefoot abduction. **B**: lateral weight-bearing radiograph shows no hindfoot equinus.

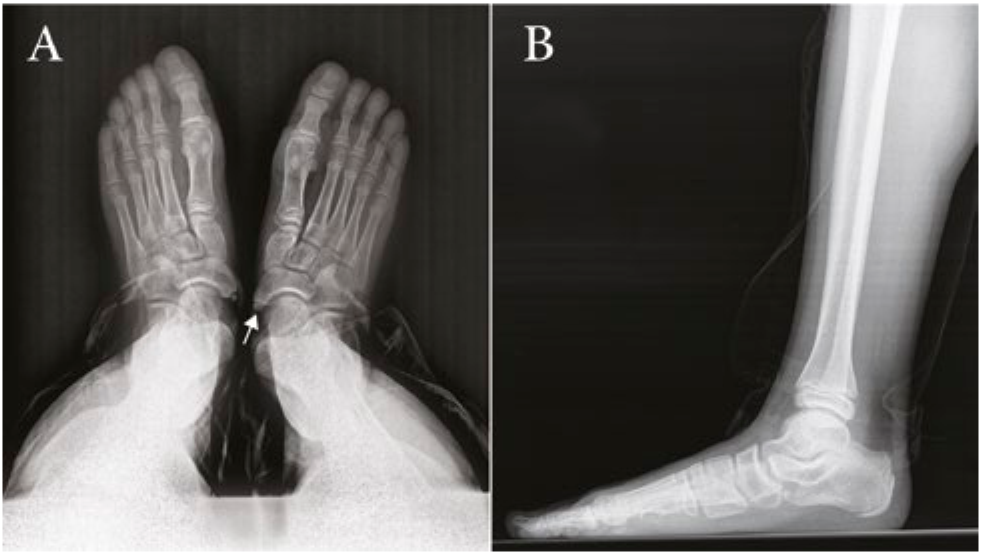

Figure 2 – 10-year-old boy with accessory navicular type II (arrow) associated with pes planus. **A**: AP-radiograph shows midfoot pronation and forefoot abduction. **B**: lateral weight-bearing radiograph shows hindfoot equinus.

patients with symptomatic AN associated with pes planus (three unilateral and four bilateral; Fig. 2). They were documented clinically and radiologically to have flattening of the medial longitudinal arch with an arch index (AI) larger than 0.32 (Murley et al., 2009). Tarsal coalition or neuromuscular causes of pes planus were excluded. For a quantitative measure of foot pronation, navicular drop test (NDT) was used. The test was performed while the subject was in bare feet. Firstly, the navicular tuberosity was marked and the height of the navicular bone (from the floor) with the subtalar joint in neutral was measured by a ruler while the patient was standing and bearing most of the weight on the contralateral limb. Then, the height of the navicular bone was measured while the patient was standing with equal weight on both feet. The difference between the first and second measurement was registered as the navicular drop (Menz, 1998). A difference higher than 10 mm was considered as significant for foot pronation (Mueller et al., 1993). Group 3 consisted of nine contralateral feet (from the 27 patients) that had AN as incidental finding with no symptoms. An age appropriate control group (30 normal individuals) was screened for the absence of AN bone, previous foot problems or surgery. Only non-pathological knees with known individual age and gender were included in this study. The intermalleolar distance with patient supine and knees together was assessed to exclude genu valgum (< 8cm). Patients with a history of traumatic injury or surgery of lower extremities were also excluded.

To measure the Q angle, both mid patellar point and tibial tubercle were determined, thereafter a line was drawn connecting the anterior superior iliac spine and mid patellar point; another line passing through the tibial tubercle was also drawn.

Finally, the Q angle was measured as the value taken between the intersected lines using a goniometer (Caylor et al., 1993; Smith et al., 2008). It should be noted that in the present study all measurements were taken during the standing position with quadriceps relaxed and with the feet together and facing forward, as the normal weight-bearing forces being applied to the knee joint mimic those occur during daily activity. All measurements were performed in triplicates by a single experienced orthopaedist and showed excellent intraobserver reliability, with correlation coefficients ranging from 0.84 to 0.89.

Statistical analyses. The data were entered into a spreadsheet and analyzed using the IBM SPSS Statistics for Windows, version 19 (IBM Corp, Armonk, NY, USA). The mean (± standard deviation), range and 95% confidence interval for the mean were calculated. Differences of continuous variables between two independent groups were assessed with two tailed t test and $P<0.05$ was taken as significant.

Results

AN group versus control group. No significant difference in age was found between the two groups. Mean, standard deviation, 95% confidence interval and range of values for Q angle and navicular drop are summarized in Table 1. The mean values of the Q angle and navicular drop for 54 lower extremities with AN were significantly higher than those of control subjects ($p<0.001$; Table 1).

Group 1 versus control group. The Q angle range for individuals with normal-arched feet without AN (60 contributing knees) was 12 to 18 in males and 14 to 21 in females. Among female patients with painful AN not associated with pes planus (22 contributing knees), 18.2 % of the knees had angles greater than 21 degrees. The data showed that three of the 13 females had angles greater than 21 degrees in at least one side. For male patients (12 contributing knees), 25 % of the knees had a Q angle greater than 18 degrees; three male subjects of the seven males had a Q angle greater than 18 degrees in one side. This group had a statistically larger navicular drop than the control group, but still their values were less than 10 mm. The mean Q angle and navicular drop values for patients with AN without pes planus were significantly higher than controls with normal arched feet in both males and females ($p<0.001$; Table 2).

Group 2 versus control group. Among female patients with AN associated with pes planus (eight contributing knees), 37.5 % of the knees had angles greater than 21 degrees. For male patients (three contributing knees), 33.3 % of the knees had a Q angle greater than 18 degrees. The data showed that the concomitant pes planus deformity was accompanied by a greater risk for developing higher Q angle values in both males and females. This group had a statistically larger navicular drop than the control group: all values were greater than 10 mm ($p<0.0001$; Table 2).

Group 3 versus control group. No significant difference in Q angle was found between the two groups in both males and females. No significant difference in NDT values was found between female patients and female controls. A significant difference in NDT values was observed in the AN asymptomatic contralateral feet of male subjects ($p<0.05$; Table 2).

Table 1 – Q angles and Navicular drop values in AN patients versus controls.

	AN group *N=54*	**Control group** *N=60*	**P**
Male			
N	18	20	
Age(years)	13.83±2.09	14.10±2.73	n.s.
Q angle ±SD	17.89±1.45	15.8±1.88	0.0005
Range	16-21	12-18	
95% CI	17.17-18.61	14.92-16.68	
NDT (mm)±SD	8.56±2.66	6.05±0.94	0.0004
Range	6-16	5-7	
95% CI	7.23-9.88	5.61-6.49	
Female			
N	36	40	
Age(years)	14.33±2.63	14.62±2.65	n.s.
Q angle ±SD	19.67±2.00	18.18±1.58	0.0005
Range	17-24	14-21	
95% CI	18.99-20.34	17.67-18.68	
NDT (mm)±SD	9.12±2.83	6.78±1.51	0.0001
Range	5-17	4-8	
95% CI	8.15-10.07	6.29-7.26	

AN: accessory navicular, NDT: navicular drop test, CI: confidence interval. n.s.: not significant.

Discussion

The overall biomechanical effect of accessory navicular bone on foot is debatable. Typically, AN is of no consequence. However, it can be a source of pain and is often associated with pes planus (Leonard and Fortin, 2010). Painful AN may also be present in feet with normal arch height and the degree of flat foot is not associated with the development and severity of symptoms in patients with AN (Sullivan and Miller, 1979; Park et al., 2014). In addition, they can present in several different locations, which can have an impact on the clinical presentation and the degree of dysfunction (Fredrick et al., 2005). In this study, we hypothesized a possible relation between the painful AN bone with or without the loss of arch height and the alignment of patellofemoral joint using Q angle measurement in early adolescence. All patients presented in this study had no knee complaints even in the presence of high Q angle, indicating a possible early sign for future patellofemoral joint complaints in these patients.

Table 2 – Mean Q angle and navicular drop values among groups.

	AN group *(N=54 feet)*			**Controls /-AN** *(N= 60 feet)*
	Group 1 Symptomatic AN/ -pp	**Group 2** Symptomatic AN/ +pp	**Group 3** Asymptomatic AN	
Male				
N	12 feet	3 feet	3 feet	20 feet
Q angle	17.58±1.31	19.33±1.53	17.67±1.53	15.8±1.88
Range	16-20	18-21	16-19	12-18
P value	0.0072	0.0056	n.s.	
NDT(mm)	7.58±1.24	13.67±2.08	7.33±0.58	6.05±0.94
Range	6-9	12-16	7-8	5-7
P	0.0004	<0.0001	0.0344	
Female				
N	22 feet	8 feet	6 feet	40 feet
Q angle	19.55±1.87	20.88±2.42	18.5±1.05	18.18±1.58
Range	17-22	18-24	17-20	14-21
P	0.0033	0.0002	n.s.	
NDT(mm)	7.86±0.81	12.63±2.39	6.83±1.33	6.78±1.51
Range	7-9	11-17	5-9	4-8
P	0.0004	<0.0001	n.s.	

AN: accessory navicular, pp: pes planus, NDT: navicular drop test. Values are expressed as means ±SD, n.s.: not significant.

The posterior tibialis muscle helps maintain the medial arch height, stabilize the subtalar joint and prevent pronation of the foot. Stabilization of the medial arch of the foot and foot position can be weakened by the abnormal insertion of its tendon due to AN, this could lead to posterior tibialis dysfunction (Bernaerts et al., 2004; Choi et al., 2004). Posterior tibialis dysfunction can lead to tendon tear, collapsing of the arch, pain and pronation of the foot. Overuse of the posterior tibialis tendon in AN patients could result in symptoms especially after activity and compromise the proper muscle function. In this study, NDT was performed to measure foot pronation. Different normal values for the NDT have been suggested in the literature (Nielsen et al., 2009; Adhikari U., 2014); however, all agree that a difference of more than 10 mm is considered as excessive foot pronation (Mueller et al., 1993). According to our measurements of control patients, the normal range was 3 to 8 mm in males and 4 to 8 mm in females. As expected, the minimum values for NDT in pes planus feet were more than 10 mm (12 mm in males and 13 mm in females), indicating excessive foot pronation in these patients. On the other hand, NDT values in patients with painful AN without fallen arch was within the high normal range, with significant higher mean values in these patient than controls (Table 1). This possibly indicates some biomechanical change, weakened arch or mild pronated position of the foot, which is mostly due to the irritation of posterior tibialis tendon by the extra accessory ossicle. The mean NDT value in male subjects with asymptomatic AN on the contralateral feet was significantly higher than in control feet; the small sample size in this category certainly has affected the reliability of the analysis. In addition, we can not preclude that asymptomatic AN is not associated with any pathological changes: it has been shown that some asymptomatic AN bones had increased radiopharmaceutical uptake using bone scintigraphy (Chiu et al., 2000).

It is well known that pes planus deformity can alter the biomechanical relationship between the foot and knee (Hetsroni et al., 2006; Gross et al., 2011). However, the increase of Q angle in adolescent patients having painful AN bone without pes planus could be explained by the increase of Q angle stress in the presence of improper foot pronation. Tiberio et al. (1987) explained in a theoretical model that a prolonged time in pronation causes excessive internal rotation of the tibia. This excessive internal tibial rotation transmits abnormal forces upward in the kinetic chain and produces medial knee stress, force vector changes of the quadriceps mechanism and lateral tracking of the patella. In agreement with this model, when the Q angle was measured with the foot in different positions, it was found that the Q angle increased as the foot shifted from outward to inward rotation (pronation) (Olerud and Berg, 1984). Additionally, a recent study suggested that high navicular drop measure may be associated with increased peak ankle and knee joint moments (Eslami et al., 2014).

Hip-knee-ankle alignment influences load distribution at the knee (Sharma et al., 2001). Any alteration in this alignment can increase the lateral force on the patella. It should be noted that valgus alignment of the knee is measured as the medial angle formed by the femur and tibia (femorotibial angle) (Brouwer et al., 2007). The degree of genu valgum can be estimated by the Q angle, while the Q angle itself is important to assess the overall lateral line of pull of the quadriceps relative to the patella, so it provides useful information mainly about the alignment of patellofemoral joint. However, in this study no valgus deformity was documented in any case, all patients had normal alignment of tibiofemoral joint and the increase in Q angle only indicates a change in the alignment of patellofemoral joint rather than the tibiofemoral joint.

The normal Q angle in males is 14 degrees ± 3, while normal value for females is 17 degrees (Aglietti et al., 1983). Values outside these limits are considered pathological burden. According to the upper limits of our measurements, standing Q angles greater than 18 degrees in males and 21 degrees in females are considered to be abnormal and indicate a tendency for added biomechanical load on the knee joint during different forms of weight bearing activity. The upper limit Q angle value for control females in this study was higher than measurements reported in other studies, reinforcing the effect of population on the Q angle as a result of the anatomical differences in pelvic anatomy (Handa et al., 2008).

Evaluation of foot deformities must include a comprehensive assessment of the lower limbs as a whole. Detection of the mechanical consequences of the AN may have implications for the prevention and/or treatment of patellofemoral complaints. For example, the use of soft foot orthotics is an effective mean of treatment for the patient with patellofemoral pain syndrome and can correct foot pronation (Hossain et al., 2011; Pinto et al., 2012).

The limitation of our study was mainly the small sample size, especially in asymptomatic AN group: a larger sample is needed in order to confirm the exact association. In addition, there is no good measure of how much pronation of the arch is optimal. NDT is a static measure of foot pronation, more dynamic parameters such as measurement of the subtalar joint displacement angle during walking are being evaluated by studies in progress.

In conclusion, AN bone should not be arbitrary considered as a normal anatomic variant. We suggest that individuals with painful AN even when it is not associated with arch collapse are more prone to have patellofemoral joint problems later in life. We recommend that Q angle assessment should be an essential component of the examination in patients with painful AN. Additionally, we recommend early prophylactic interventions such as quadriceps exercises, posterior tibialis strengthening exercises, and soft foot orthotics to limit foot pronation and prevent the potential future consequences on patellofemoral joint in early adolescence when it is a common time for the symptoms to first appear.

Conflict of interest statement

The authors declare that the research was conducted without any commercial or financial relationships that could be seen as a potential conflict of interest

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